

# 66

## Speech and Other Lateralizing Cortical Functions

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### Definition

The following functions need to be tested only when an abnormality is suspected and not as part of a routine screening examination:

Function	Abnormality
<i>Speech</i>	
Phonation	Dysphonia, aphonia
Articulation	Dysarthria, anarthria
Language	Dysphasia, aphasia
<i>Other dominant hemisphere functions</i>	
Right-left orientation	Right-left disorientation
Finger identification	Finger agnosia
Calculation	Acalculia
<i>Nondominant hemisphere functions</i>	
Drawing ability	Drawing apraxia
Topographic ability	Spatial disorientation
Construction	Constructional apraxia
Dressing	Dressing apraxia
Facial recognition	Prosopagnosia
Awareness of body and space	Neglect of part of body or space
Motor persistence	Motor impersistence
<i>Bilateral hemisphere functions</i>	
Motor performance	Motor apraxia
Handedness and other lateralized motor functions	None

### Technique

#### Speech

The components of speech to be tested are phonation, articulation, and language. These components need to be carefully tested only when dysfunction is suspected and not as a routine screening procedure. The order in which the tests are performed will vary. In many cases the language component, especially comprehension, will have to be tested before proceeding to other tests which require intact comprehension.

**Phonation.** Ask the patient to say "ahh . . ." as long as possible. Note whether spontaneous speech is hoarse or whispery. The vagus nerve and the larynx are being tested here. (See Chapter 63, Cranial Nerves IX and X. Also see Chapter 69, The Cerebellum, since cerebellar dysfunction can cause abnormalities in this test.)

**Articulation.** These tests involve the muscles and structures responsible for forming words: pharynx, tongue, teeth, and lips. Innervation is from nerves V, VII, IX, X, XI, and XII.

The soft palate must elevate and close the nasopharynx in order to produce guttural sounds such as "gut" or "kuh." Inspect palatal elevation as the patient says "ah." Ask the patient to say "gut, gut, gut" and "kuh, kuh, kuh." Palatal closure can also be tested by stimulating the gag reflex on each side while observing the palate.

An idea of the function of the tongue can be gotten from having the patient say "la, la, la." The lips are tested by "me, me, me." Some disorders, such as myasthenia gravis, produce easy fatigability of these structures. Some idea about strength of respiratory muscles can be obtained by having the patient rapidly count to 30.

Test phrases and words hallowed by usage can also be used to evaluate articulation:

Hippopotamus  
Methodist Episcopal  
Third riding artillery brigade  
Truly rural  
Constantinople is the capital of Turkey  
Magnolia Petroleum Corporation  
Peter Piper picked a peck of pickled peppers  
Round the rugged rock the ragged rascal ran

Table 66.1 summarizes the tests for phonation and articulation.

**Language.** The outline below follows that given by Geschwind.

1. Spontaneous speech. Spontaneous speech is best evaluated when the patient speaks at some length. The present illness query usually elicits a statement of some length. Also use questions such as: What did you do today before coming to see me? Describe your occupation. How do you perform [a particular task the patient is known to do]? How do you make a cake?

An important feature of many cases of aphasia is that the dysfunction can be minimal; aphasia is not an all-or-nothing condition. As the patient speaks, listen carefully and note:

**Table 66.1**  
Phonation and Articulation

Test	Structure
Ah	Larynx and expiratory muscles
Gut, kuh	Pharynx
La, la, la	Tongue
Me, me, me	Lips
Words, phrases, counting	All structures

- a. *Fluency*: Words per unit of time. Place the patient into one of three groups: fluent, normal, non-fluent.
  - b. *Circumlocution*: Use of phrases such as "what you eat with" instead of fork, or "what you write with" instead of pen.
  - c. *"Empty" words*: Using generalized, nonspecific terms to refer to specific objects: "thing," "place," "these." The patient never gets to the "punchline" words.
  - d. *Paraphasia*: A common and important finding in aphasia. Phonemic or literal paraphasia is the substitution, addition, or deletion of phonemes: fish for dish, Kenry Hissinger for Henry Kissinger. Verbal or semantic paraphasia is the use of an incorrect word: "I cleaned my fingernails with an ice pick." Neologism is applied to speech when the source word is unrecognizable. Paraphasic speech commonly combines all these types.
  - e. *Word-finding difficulty*: Frequent hesitation before coming up with words (especially nouns), and at times using the wrong word.
  - f. *Delayed response to questions*: A delay in or difficulty in answering questions.
  - g. *Anxiety about speech*: Many patients are aware of their problems and become agitated when confronted with tasks involving language.
  - h. *Perseveration*: Using the same word over and over. Example: If asked to name a pencil, the patient will say "pencil" for each succeeding object regardless of what it is.
  - i. Note especially the handling of small grammatical words and numbers versus the handling of nouns. Some aphasic patients will handle the small words and/or numbers with much greater ease than nouns.
2. *Comprehension*
    - a. *Spoken language*
      1. Use questions that can be answered by yes or no: Do you feel well? Do you live at . . . ? Is this month . . . ?
      2. Ask the patient to point at body parts (nose, leg) and objects in the room (chair, picture).
      3. Have the patient perform simple activities on command: Touch your nose. Move the chair.
    - b. *Written language*
      1. Write a few simple questions and commands on paper such as: Show me your nose. Point to a chair. Is this month . . . ?
  3. *Repetition*. Ask the patient to repeat
    - a. Letters
    - b. Numbers
    - c. Words
    - d. Sentences
  4. *Naming*. Show objects such as: comb, key, coin, bill-fold, watch, crystal on watch, winding stem on watch, tie, thumb, or fingers of patient or examiner. Do this rapidly, asking the patient to name each. Many examples of minimal aphasia are brought out only after showing the objects rapidly and repeating the sequence of objects in rapid succession.
  5. *Writing*. Use numbers, letters, words, and sentences such as these taken from a first-grade reader: We saw the horse run. A strong wind began to blow and blow.
 

Test the patient's ability to write by:

    - a. Command
    - b. Dictation
    - c. Copying

### *Other Dominant Hemisphere Functions*

Note that some of these tests will have been performed previously. These tests are not necessary on routine screening examinations but only when cortical function is suspected to be impaired.

*Right-left orientation*. Ask the patient to demonstrate various right and left parts of his or her own and the examiner's body. Command the patient to turn first in one, then the other direction. Ask the patient to say whether specific objects in the room are to the right or left of the patient.

*Finger identification*. Ask the patient to hold up the index finger, then the thumb, and then to identify the examiner's fingers. Then touch the finger on one hand and ask the patient to move the same finger on the other hand.

*Calculation*. Give oral and written tasks involving addition and multiplication, geared to educational level of patient.

### *Nondominant Hemisphere Functions*

*Drawing ability*. Ask the patient to draw various shapes: triangle, square, daisy, bicycle, clock. Test the patient's ability to do this (1) by command, (2) by copying, and (3) by choosing correct shape from several drawn by examiner.

*Topographic ability*. Ask the patient to:

1. Draw outline of United States.
2. Describe north-south-east-west relationship of various places in relation to each other or patient: home, famous local places, New York.
3. Draw map of patient's home, or tell how to get from one place to another in the home, or from home to store.

*Construction*. The examiner takes tongue blades and has the patient first on command and then by copying form various designs: square, triangle.

*Dressing*. Hand the patient a shirt or robe and observe the ability to dress.

*Facial recognition*. Carry several 2 × 2 photographs of faces. Point out two, and later ask the patient to choose them from among the others. Also obtain history regarding facial recognition from family members and ward personnel. This refers to face recognition without auditory recognition: Patients with certain lesions can recognize the person when the voice is heard.

*Awareness of body and space*. Observe for neglect of one-half of the body or surrounding space. Determine whether awareness of defect is present.

### *Bilateral Hemisphere Functions*

*Motor performance* ("praxis"). The ability of the patient to perform simple and complex motor actions is tested in three ways:

1. By command
2. By imitation of examiner
3. By manipulating an object

Each side of the body must be tested.

1. Face:
  - stick out tongue
  - blow out cheeks

- purse lips  
 make a kiss  
 2. Hands:  
   make fist  
   wave goodbye  
   throw a kiss  
   shake hands  
   give military salute  
   pretend to play piano  
   use a key, comb, toothbrush  
   wind watch  
 3. Feet:  
   walk normally  
   draw circle on floor with toe  
   stamp foot  
   kick ball

*Handedness*, or laterality of motor functions. Determine the laterality of the following functions:

1. Dominant hand: Use of pen or eating utensils.
2. Dominant eye: Eye camera is held to. Or have patient line a finger up with a vertical line in the room: picture frame, crack in wall. Do this with both eyes open. Then close first one eye and then the other. The patient will discover only one eye has lined up the finger: this is the dominant eye.
3. Dominant foot: Which foot is used to kick a ball or to hop?

## Basic Science

What follows is a fairly simple and diagrammatic approach to how the cortex handles higher functions. Our current knowledge is quite incomplete. There are a number of different concepts concerning how the cortex handles language. The concept outlined here is clinically useful and can be "taken to the bedside." This outline is based upon the elegant discussions of Geschwind (1965). Other approaches that can be used are covered in the References.

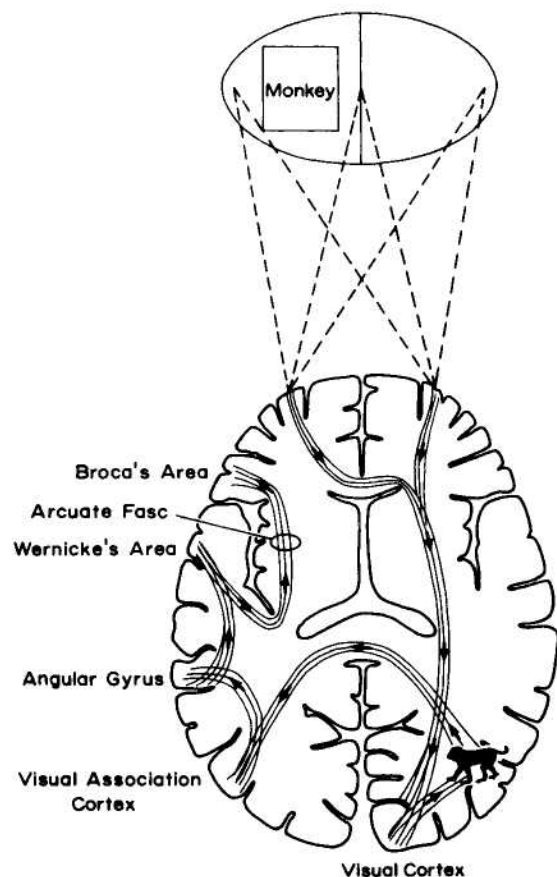
### *The Dominant Hemisphere*

The cerebral cortex receives sensory impulses, integrates them, and produces a motor response, "speech." In the great majority of individuals this is largely a function of the left or "dominant" hemisphere.

We will trace the path of a visual stimulus from the time of reading the word "monkey" through the spoken word (Figure 66.1). We will begin with the word in the left visual field for the purpose of illustrating certain features of the corpus callosum. Normally, of course, the word is perceived in both visual fields.

After "monkey" is seen in the left visual field, the stimulus goes to the right visual or calcarine cortex (area 17 of Brodmann). See Chapters 115, Visual Acuity, and 116, Visual Fields, for a description of the path taken. The stimulus next is transferred to a contiguous area of cortex, the visual association cortex of the parietal (areas 18 and 19 of Brodmann) and occipital lobes.

The concept of *association areas* is quite important. Current views of cerebral organization follow Flechsig's rule (see Geschwind, 1965). The gray matter of the cerebral cortex is composed of two types: primary cortex and as-



**Figure 66.1**

Pathway taken by a visual impulse, beginning with perception of image in visual field and ending with Broca's area. For the purposes of discussion, the image is shown only in the left visual field. Adapted from *Language and the Brain*, by N. Geschwind. Copyright 1972 by Scientific American, Inc. All rights reserved. Used with permission.

sociation cortex. The principal primary areas include vision, hearing, sensory, and motor cortex. Each of these areas is connected only to the part of the body served (e.g., retina for visual cortex) and to surrounding cortex by short U fibers. This surrounding or adjacent cortex is termed *association cortex* (Table 66.2). The association cortex is connected to other association areas within the same hemisphere (intrahemispheric fibers) and to the sibling association area in the opposite hemisphere (transcallosal fibers). For example, the calcarine cortex of the right side has no direct connections with the left calcarine cortex or any other distant cortical areas. It is connected only to the retina by the visual radiation and to the adjacent visual association cortex of the occipital and parietal lobes. The visual association cortex, however, is connected to various areas in the cortex of the same hemisphere by intrahemispheric fibers, as well as the visual association cortex of the opposite hemisphere by transcallosal fibers that cross in the posterior portion (splenium) of the corpus callosum.

Similarly, there is a motor association cortex (the part dealing with the muscles of speech is Broca's area), a hearing association cortex (Wernicke's area), and a somesthetic association cortex (no eponym). These association areas have extensive distant cortical connections, quite in contrast to the absence of such connections in the case of the primary areas. The association areas of each side are connected by



**Table 66.2**  
Cerebral Organization

Primary cortex	Association area
Motor speech	Broca's area
Somesthetic	Somesthetic association area
Hearing (Heschl)	Wernicke's area
Vision	Visual association cortex
—	Supramarginal and angular gyri

the corpus callosum. The visual association cortex of each side has intrahemispheric connections with the supramarginal and angular gyri of the same side, which in turn are connected to the hearing association cortex (see Figure 66.1). The hearing association cortex, Wernicke's area, is connected with the motor association cortex, Broca's area. The cortical integration of sensory impulses and the production of motor responses is carried out through the connections of the association areas. The most prominent connection is the corpus callosum, which connects each right area with its sibling on the left. The arcuate fasciculus connects Wernicke's and Broca's areas. Other connections within each hemisphere are not so anatomically discrete and have not been worked out in detail. Important clinical consequences follow the disconnection of various areas; these disconnection syndromes will be discussed later.

Let us return to the path taken by the visual stimulus "monkey." After being processed by the right visual association cortex, the impulse crosses through the corpus callosum to the left visual association cortex.

The next station is the supramarginal and angular gyri of the left parietal lobe. The supramarginal and angular gyri might be viewed as the granddaddy of the association areas, or the "association area of the association areas." They form the inferior parietal lobule (areas 39 and 40 of Brodmann). This area, which is highly developed in humans, is either rudimentary or absent in other higher mammals such as the apes. It is one of the last areas of the human brain to myelinate. Geschwind has suggested that this area is involved in connecting a sensory stimulus (here, the written word monkey and perhaps the visual image monkey) with its spoken equivalent ("monkey"). This suggestion is supported by the anatomy of the connections of these gyri (the contiguity of the visual association cortex and the hearing association cortex) and by the clinical observation that discrete lesions can produce anomia. In this form of aphasia, small grammatical words (articles, adverbs) are present but the patient is bereft of nouns.

The next station is the hearing association cortex (Wernicke's area). The primary cortex and the association cortex are in the superior temporal gyrus near its posterior end. Collectively they constitute areas 41, 42, and 22 of Brodmann. Wernicke's area can be thought of as the "storehouse" of auditory associations (Geschwind, 1965). All words, at least nouns, must be processed in Wernicke's area before they are comprehended. This is apparently true of both spoken and written words and presumably is related to the fact that humans use spoken words before they learn written words. It is as if the brain has to hear the word "monkey" spoken internally before it can comprehend the word even when the word is read. This explains why comprehension for both spoken and written language is lost in lesions of Wernicke's area. One way to look at the functions of the three association areas described thus far (visual, angular-

supramarginal, and hearing) is to conceive of the angular-supramarginal gyri on one side receiving the visual image of a monkey and on the other side "scanning" Wernicke's area to discover the spoken word that matches up with the visual image. Comprehension perhaps occurs when these two are matched or "associated."

Note that if the word "monkey" had been spoken instead of read as in our example, it would have gone immediately to the primary hearing cortex and thence to Wernicke's area. Presumably the angular-supramarginal gyri would have been activated then and told to "scan" the visual association cortex for the image that matches the word.

The stimulus "monkey" now goes from Wernicke's area to a portion of the motor association cortex known as Broca's area. It is located in the posterior portion of the third frontal gyrus (pars opercularis). Broca's area probably largely corresponds to Brodmann's area 44, although Mohr (1976) points out that it has no unique histological features. Broca's area is the association area of the primary motor cortex for speech. The question arises as to how the motor association cortex is related to the primary motor cortex. The primary motor cortex activates the individual muscles that participate in the action. Apparently, the knowledge of the sequence of muscle activation is contained in the motor association cortex. To put it another way, the "memory" or code for which muscles to activate and when to activate them is present in the motor association cortex. A lesion of the association cortex will result in inability to carry out a certain action, such as walking, waving goodbye, or making a fist on command, even though the strength is present. This is called *apraxia*. It is a loss of the memory of motor performance. Lesions of Broca's area will result in loss of the memory of how to speak words. Comprehension will be intact since Wernicke's and other posterior areas are intact. The final cortical station for "monkey" is the primary motor cortex which, under the direction of Broca's area, activates the specific muscles necessary to speak the word. Table 66.3 summarizes the functions and locations of the language areas.

The relationship between language dominance and cerebral dominance for motor functions has been the subject of much discussion. Individuals can be characterized as to sidedness in terms of hands, eyes, ears, feet, and probably jaws also. Handedness and footedness are well correlated in right-handed persons (95%) but not as well correlated in left-handed individuals (50%). Correlations between handedness and eye dominance have not been clearly demonstrated. There is a problem in the definition of what constitutes handedness since many individuals have a preferred hand for a specific task: eg, writing will be done by the right hand and swinging a bat by the left. Using a battery of tests on a number of individuals, Subirana reported:

Pure right-handed	24%
Strong right-handed predominance	39%
Weak right-handed predominance	17%
Weak left-handed predominance	10%
Strong left-handed predominance	10%
Pure left-handed	0%

One can easily see why there might be some confusion in the literature concerning the relationship of dominance for handedness to dominance for speech, especially since it is

**Table 66.3**  
Areas Involved in Language

Area	Location	Function
Primary motor cortex	Precentral gyrus, area 4	Converts information from Broca's area into motor activity that produces speech.
Broca's area	Left third frontal gyrus, posterior portion (pars opercularis)	The motor association cortex for the face, tongue, lips, palate, pharynx, and respiration. Contains the "motor patterns" necessary to produce speech.
Arcuate fasciculus	A band of white fibers that connect Wernicke's area to Broca's area	Carries information from Wernicke's area to Broca's area.
Primary auditory cortex	Areas 41 and 42—the transverse gyri of the superior temporal convolution	Receives and analyzes auditory information.
Wernicke's area	Posterior portion of left superior temporal gyrus	The auditory association cortex. Analyzes incoming motor signals from the primary auditory cortex and probably makes sense out of them by matching incoming patterns and previously analyzed patterns stored in a memory bank. Necessary for both repetition and comprehension.
Perisylvian region	The area immediately surrounding the Sylvian fissure	Includes Broca's area, arcuate fasciculus, and Wernicke's area.
Border zone or watershed area	The area between the supply of the middle cerebral artery and the posterior cerebral— anterior cerebral arteries	Site of lesions producing the transcortical aphasia. The common denominator of these aphasia is that repetition is not disturbed, because Wernicke's area remains connected to Broca's area.
Angular gyrus and supra-marginal gyrus	Form the inferior portion of the parietal lobe; they are at the confluence of auditory, somesthetic, and visual association cortices	Serve to connect the three association cortices to each other. When presented with visual information they scan Wernicke's area and arouse auditory information that matches the visual material. In a similar fashion they scan the visual association cortex when presented with auditory information.
Visual association cortex	Areas 18 and 19 of the occipital and parietal lobes just anterior to primary visual cortex	The area where primary visual information is analyzed.
Corpus callosum	Connects right and left cerebral hemispheres	Connects the sibling areas of each hemisphere.

almost impossible to perform a battery of tests for handedness on aphasic patients.

Roberts has collected the following information from the literature with regard to aphasia and cerebral dominance for handedness: In left-handed patients, aphasia is twice as frequent with lesions of the left hemisphere as it is with lesions of the right hemisphere. If there is aphasia in a patient with a lesion of the right hemisphere, the patient is 13 times more likely to be left-handed than right-handed.

There is some evidence that there may be bilateral cortical representation for speech in left-handers but not right-handers (Milner et al., 1966).

The question of determining cerebral dominance for speech is important clinically in planning neurosurgical operations and in attempting to localize the lesion in certain cases of aphasia. There is little problem in this correlation with "pure" right-handers, but progressively less correlation as the "pure" left-handed part of the spectrum is approached.

Other functions that are unique to the dominant hemisphere include: right-left orientation, finger identification, and calculation. Constructional apraxia can be seen in dominant hemisphere lesions, although it is less severe than when it occurs with nondominant hemisphere lesions.

### *The Nondominant Hemisphere*

The right hemisphere has often been characterized as the "nondominant" or "minor" hemisphere or "the other side of the brain" in recognition of the fact that language func-

tions in the great majority of people (whether right- or left-handed) are largely present in the left hemisphere. The uniqueness of the left hemisphere for language was discovered by Broca and Dax. Since that time, much has been written on whether the right hemisphere has any unique functions. A view widely held for many years was that the right hemisphere was "mute and illiterate." One large problem is that it is difficult to compare performance in two patients who have similarly located lesions, one with a lesion in the left and the other with the lesion in the right hemisphere. The patient with the left hemisphere lesion often has aphasia and cannot be tested in the same way as the patient with the right hemisphere lesion.

A great stimulus to the question came in the early 1960s with a series of reports by Sperry and his colleagues on patients in whom the corpus callosum, the anterior commissure, and the hippocampal commissure had been transected in an attempt to control intractable epilepsy. In these patients with "split brains" it was possible to test the separate functions of the hemispheres. The following account of one of their patients, "W. J.," is taken from Pines (1973). W. J. would obey commands such as "raise your arm" involving the right side of his body but did not obey the same commands involving the left side. When blindfolded, he could identify where he was touched on the right side but not on the left side. His left hand would do things that his right hand "deplored": one hand would pull his pants down while the other was pulling them up; on another occasion he threatened his wife with his left hand while his right hand tried to restrain the left hand. The right hemisphere was unable to do tasks which required language comprehension.

These observations seemed to bear out the suspicion that the right hemisphere was mute, illiterate, and imbecilic when compared to its language-endowed twin. Then one day W. J. was given the task of copying a Greek cross. The right hand was unable to do this; a few disconnected lines were drawn. But the left hand copied the outline swiftly and surely. On other occasions, W. J. could easily arrange colored blocks according to a diagram with his left hand but could not even begin to do as well with his right hand. These observations suggested the right hemisphere is superior to the left in visuospatial relationships.

Reports by other workers also suggest that the right hemisphere may be superior to the left in certain areas involving visuospatial relationships. Below are listed some functions that may be either unique to or at least done better by the right hemisphere. The review by Joynt and Goldstein (1975) and Benton's discussion in the *Handbook of Clinical Neurology* (1969) summarize the evidence for and against the idea of the right hemispheric localization of these functions.

#### 1. *Spatial orientation*

a. *Extrapersonal space.* Patients with lesions of the right hemisphere can neglect the left half of their visual space. There are problems with route-finding, even in familiar surroundings such as their own home, reading maps, and topographic memory. See Benton for a good review.

b. *Personal space.* The left half of the body is neglected just as the left half of space. In the words of a patient of Lhermitte: "I have lost my left half." The spatial perception of body structure is disordered.

2. *Construction.* The right hemisphere can comprehend patterns and diagrams better than the left. Thus patients with right hemisphere lesions can have what is termed constructional apraxia: they have difficulty assembling, building, and drawing. This is probably secondary to the defect in spatial orientation described above. One way of describing some of these problems is that they deal with "part-whole" relationships. The patients cannot see part of a pattern and deduce what the whole pattern will look like, even in a test such as the examiner drawing a part of a circle and asking the patient to complete the circle. Pattern recognition may well be one of the unique properties of the right hemisphere.

3. *Clothes dressing.* A prominent sign of a right hemisphere lesion can be "dressing apraxia," a severe difficulty in putting on an article of clothing or even an inability to dress. This involves perceiving the spatial relationships of a garment and relating them to the spatial structure of the body.

4. *Facial recognition.* The ability to recognize faces can be lost. Joynt and Goldstein report that a patient of Charcot's "misinterpreted his reflection in a mirror as another person and stepped aside to let him pass." Facial identification involves the recognition of visuospatial patterns of faces. Some of these patients use speech or other cues to recognize people.

5. *Motor persistence.* Patients with right hemisphere lesions may not maintain a motor act such as keeping the eyes closed, maintaining fixation of gaze to one side, keeping the mouth open, or keeping the tongue protruded (Fischer, 1956). There are no good speculations as to the mechanism.

### *The Corpus Callosum*

For many years the role of the corpus callosum was unknown. There were no discernible differences between patients and animals in whom it was absent or had been transected, and in normals. The tongue-in-cheek suggestion was that it existed "to keep the hemispheres from sagging." But beginning in the 1950s Sperry, Myers, Gazzaniga, and others reported a series of experiments that began to shed light on the functioning of the corpus callosum and also contributed to an understanding of the abilities of each hemisphere. Myers' experiments in callosum-sectioned cats and monkeys (summarized by Sperry in 1961) demonstrated:

1. When both the corpus callosum and optic chiasm are split so that information presented to the left eye goes only to the left hemisphere and that presented to the right goes only to the right hemisphere, the animal is unable to perform with the right eye and right hemisphere tasks that were learned with the left eye and left hemisphere. There is "a complete amnesia for the visual training experienced with the first eye."
2. If only the optic chiasm is cut, tasks learned by one eye are readily performed by the other eye.
3. If the animal has the optic chiasm cut, is trained with the left eye, and then has the callosum cut, both eyes still perform the task learned by one eye: the learning is transferred from one hemisphere to the other via the corpus callosum. In Sperry's words (1961): "... the corpus callosum is shown to be instrumental in laying down a second set of memory traces, or engrams, in the contralateral hemisphere—a mirror image duplicate."

Some of the dysfunctions in patients with callosal section were seen in W. J., described earlier in this section. Gazzaniga (1972) has reported some illuminating experiments on human subjects who were tested in such a fashion that visually presented information went only to one hemisphere or the other (by showing the stimulus rapidly in either the left or the right visual field):

1. When the response of the subject was to say yes if a dot appeared in the visual field, the response occurred 30 msec faster when the dot was presented to the left hemisphere. Presumably the 30 msec longer that occurred when the information was presented to the right hemisphere was at least partially due to time used for transfer across the callosum.
2. Tasks requiring verbal processing were done more quickly when the information was first presented to the left hemisphere.
3. When the task was for the subject to indicate manually if information presented was identical (AA would require a response; AB or Ab would not), both hemispheres were equally adept.
4. If the task was to indicate if letters belonged to the same class (Aa would require a response; Ab would not), the left hemisphere responded faster than the right.
5. Tasks requiring visual pattern discrimination (e.g., judging which of two zigzag figures are oriented in the same direction) were done 14 msec faster by the right hemisphere than the left.



An interesting experiment by Levy, Trevarthen, and Sperry (1972) with split-brain patients involved taking pictures of faces and cutting them in half, then pasting various combinations together—such as half an old man's face to half a young woman's face. This composite picture was then flashed briefly on a screen so that one-half went to the right hemisphere and the other half to the left hemisphere. After seeing the composite picture the subjects were shown the original uncut pictures and asked to pick the one seen on the screen. They invariably picked the one whose half-face had been presented to the right hemisphere, thus lending support to the clinical observation that facial recognition is a function of the right hemisphere. But if asked to *tell* which face was seen, the subjects described the half-face presented to the left hemisphere.

In summary, our knowledge of possible unique hemispheric functions and the role of the corpus callosum is presently rudimentary and much of it is speculative. The function of the corpus callosum appears to be to transfer information from one hemisphere to the other. If indeed each hemisphere has unique functions, the role of the callosum may be to make available to one hemisphere the knowledge or special abilities of the other. An example could be the interpretation of an electrocardiogram: the right hemisphere recognizes the "pattern" while the left hemisphere analyzes the information in detail. The corpus callosum enables the hemispheres to work together, each doing what it can do best. Ultimately, information from the right hemisphere is passed to the left via the callosum, integrated with the analysis by the left hemisphere, and expressed in a "verbal package" assembled by the left hemisphere.

### Clinical Significance

In this discussion of the types of aphasia, we will begin with Broca's area and proceed posteriorly.

#### *Broca's Aphasia*

In Broca's aphasia (motor aphasia, expressive aphasia, anterior aphasia, nonfluent aphasia), word production is sparse ("nonfluent") and words are emitted with great effort. Grammar is simplified, and sentence structure is condensed—"agrammatism." Content is largely nouns and action verbs with little use of small filler words, leading to the term "telegraphic speech." Rhythm and melody are disturbed. Writing is always abnormal. Most patients have an associated right hemiplegia due to involvement of the primary motor cortex. Repetition is quite abnormal. Auditory and visual comprehension is either intact or largely so, since the posterior speech areas are not affected. Patients become very frustrated and angry as they hear themselves speak, since self-monitoring is intact due to the fact that the posterior speech areas are spared. The lesion involves Broca's area. Buccofacial and respiratory apraxia is present: on command the patient is unable to perform such activities as sticking out the tongue, puckering the lips, whistling, coughing, sniffing, and the like. Apraxia of the left upper extremity is present. A fascinating aspect of this type of aphasia is that many patients have intact singing, swearing, and serial speech (such as counting, months of the year, etc.) (Yamadori et al., 1977).

Mohr (1976, 1978) does not feel that the classic view of Broca's apraxia presented above corresponds to clinical and

autopsy material. He describes two different syndromes. In the first, small lesions limited to Broca's area produce a spectrum of features. The mildest cases have a very slight disturbance in the melody of speech, in which "the mechanisms of speech are suddenly altered in such a way as to be possibly more apparent to the victim than the beholder." Severely affected patients are mute and have severe dyspraxia of both upper extremities and of oral, buccal, lingual, and respiratory function. No agrammatism or other features of Broca's aphasia described above are present, although there is some slight degree of language disorder when the patient is tested carefully. Improvement in the mute patients is rapid, with emergence of dysarthric speech that has no elements of aphasia. The lesions in these cases are small, discrete infarcts produced by emboli lying at the origin of the anterior branches of the upper division of the left middle cerebral artery.

In the second syndrome described by Mohr, large lesions are present in the Sylvian region involving the operculum, including Broca's area, the insula, and the adjacent cerebral cortex in the territory supplied by the upper division of the middle cerebral artery. These patients have a very different clinical picture from the one described for Broca's area infarcts. Initially there is mutism and profound total aphasia, in contrast to mutism with very faint evidence of aphasia in the patients with lesions limited to Broca's area. Over time the mutism and aphasia evolve into the classic picture of Broca's aphasia: agrammatism, telegraphic speech, and other disturbances of language and communication as described. This picture is present only months or years after the onset of illness. Mohr's conclusions (1977) are as follows:

Cases of embolic or hemorrhagic stroke affecting the anterior superior Sylvian region, including the operculum, insula, and subjacent white matter, appear to produce a spectrum of deficits predicted both by lesion site and size.

Broca's area appears to be but one of many regions along the Sylvian region that integrate with one another to allow speaking. The brain appears to be able to overcome Broca's area infarction, perhaps by recruitment of adjacent regions on the same side or by transcallosal pathways through the minor hemisphere. Mutism, then vocal apraxia, not a central language disorder, seem to result from Broca's area infarction.

The larger disorder referred to as Broca's aphasia appears to require a much larger lesion, involving most of the upper operculum and insula. The spread of deficit into tasks other than speaking indicates a more fundamental disorder shared by all modalities of speech production and reception. The linguistic features are different from Wernicke's aphasia, and seem distinctive.

The requirement that the lesion be larger than Broca's area suggests Broca's area may not be important for language function itself. It suggests that the language function mediated by the Sylvian operculum and insula might, by analogy with an orchestra, be a synergistic product of more elementary individual speech functions accomplished all along the region, and be resistant to significant persisting functional loss until enough elements have been lost that their cooperative results are no longer recognizable.

#### *Conduction Aphasia*

In conduction aphasia (central aphasia of Kurt Goldstein), three features are characteristically present (Benson et al.,

1973): (1) Fluent speech—though not so fluent as Wernicke's aphasia—with notable paraphasia. The paraphasia is commonly literal (fish for dish). Patients often become quite frustrated as they hear themselves speak, indicating the posterior speech areas are functioning as monitors. (2) Normal comprehension. (3) Grossly defective repetition. These three conditions must be met to make the diagnosis. Additional common but not necessary features include: (1) anomia of variable degree; (2) inability to read aloud (due to repetition disturbances), although silent reading is normal in terms of comprehension; (3) dysgraphia, varying from mild misspellings to complete agraphia; (4) buccofacial and bilateral upper limb apraxia in the face of mild or absent motor deficits; (5) other neurologic abnormalities including a mild right hemiparesis and hemisensory deficit.

The most common lesion lies deep to the supramarginal gyrus, in the left anterior and inferior parietal area. This lesion interrupts the arcuate fasciculus connecting Wernicke's and Broca's areas. A less common location is a lesion which destroys the first temporal gyrus on the left, obliterating all of the left auditory cortex. Apraxia is associated with the former lesion but not the latter.

### Wernicke's Aphasia

Wernicke's aphasia (receptive aphasia, sensory aphasia, fluent aphasia, posterior aphasia) consists of an outpouring of words with absent comprehension and repetition. Broca's area is running on and on without any control from the posterior

speech area of Wernicke. Since Wernicke's area is required for the comprehension of both spoken and written words, it is understandable that comprehension—written or spoken—and repetition are both defective. Paraphasia is common. The patient's speech is continuous and rapid—"logorrhea"—and the physician has little or no opportunity to get a word in. Such patients are usually very disruptive influences on the wards and in the home and often have to be institutionalized. On occasion, Wernicke's aphasia may occur initially and then evolve into a conduction aphasia. A consideration of the lesion of Wernicke's—the posterior part of the superior temporal gyrus (auditory association cortex)—and that described above for conduction aphasia makes this understandable. An interesting feature of Wernicke's aphasia is that commands involving the entire body ("stand up," "turn around") are often intact, suggesting the right hemisphere plays a role in understanding this type of command (Table 66.4).

### Transcortical Aphasias

Transcortical lesions may isolate the speech area or affect the motor or sensory components of speech.

*Isolation of speech area.* The lesion leaves the perisylvian structures intact and connected to each other but cut off from the rest of the cortex by extensive destruction of the entire border zone. Since Wernicke's area is connected to Broca's area, repetition is intact. Characteristics of a case reported by Quadfasel, Segarra, and Geschwind are:

**Table 66.4**  
Simplified Aphasia Summary

Description	Fluency	Repetition	Comprehension	Lesion
<b>Broca's</b>				
Agrammatic telegraphic speech uttered with great effort and frustration.	Nonfluent	Impaired	Intact	Broca's area and perhaps much more.
<b>Conduction</b>				
Paraphasia and severe repetition disturbance, with normal comprehension	Fluent	Impaired	Intact	Lesion deep to the left supramarginal gyrus, destroying the arcuate fasciculus. Less often a lesion obliterating the first temporal gyrus.
<b>Wernicke's</b>				
Fluent paraphasic speech	Fluent	Impaired	Impaired	Posterior portion of the left superior temporal gyrus.
<b>Transcortical aphasia</b>				
1. Isolated speech area: repetition strikingly intact—to point of echolalia—but comprehension nonexistent.	Fluent	Intact	Absent	Border zone.
2. Transcortical motor aphasia: nonfluent speech, lack of spontaneous speech, but remarkably intact repetition.	Nonfluent	Intact	Intact	In frontal lobe anterior or superior to Broca's area.
3. Transcortical sensory aphasia: Repetition intact, no comprehension.	Fluent	Intact	Absent	Border zone parietotemporooccipital lobes.
<b>Anomic aphasia</b>				
No nouns.	Fluent	Intact	Varies	Left angular gyrus when marked.
<b>Pure word deafness</b>				
Cannot understand the spoken word, but normal comprehension of writing.	Normal	Absent to voice	Absent to voice	Bilateral temporal lobe lesions, or deep in left posterior temporal lobe.
<b>Alexia without agraphia</b>				
Pure word blindness. Can understand spoken but not written word.	Normal	Absent to reading	Absent to reading	Left visual cortex and splenium of the corpus callosum.
<b>Alexia with agraphia</b>				
Cannot read or write. Gerstmann's syndrome often present, plus anomia.	Normal	Present to voice	Present to voice	Dominant angular gyrus.



1. Absent spontaneous speech and lack of comprehension.
2. Intact repetition in addition to completion of certain phrases. For example, when "Roses are red . . ." was said to her, she would say "Roses are red, violets are blue, sugar is sweet, and so are you." She could learn new songs and sing them. She would repeat sentences said to her in a parrotlike fashion (echolalia).
3. Penmanship was intact (since Broca's area was intact) but writing was absent. For example, the patient could copy but not express ideas. Comprehension was absent because connections to other cortical areas were lacking. Written material could not be connected to Wernicke's area for verbal expression and therefore comprehension. Similarly, spoken information did not have access to the visual association area so images could not be aroused by speech.

*Transcortical motor aphasia.* The disturbance is produced by a lesion in the frontal lobe anterior or superior to Broca's area. Speech is nonfluent and comprehension is relatively preserved, producing a similarity to Broca's aphasia. However, repetition is remarkably preserved: the patient can easily repeat long sentences that are phonetically and syntactically complex. Upper extremity weakness may be more pronounced proximally than distally because of the watershed distribution (Rubens, 1976).

*Transcortical sensory aphasia.* Large lesions in the watershed distribution of the parietooccipitotemporal areas destroy the connection of these areas with Wernicke's area, which again remains connected to Broca's area. Comprehension is defective, as one would expect. Once again the patient can effortlessly repeat long complex sentences.

### Other Aphasias

*Anomic aphasia.* Fluent, empty speech is strikingly devoid of substantive words such as nouns and action verbs. Repetition is intact. Comprehension varies from intact to impaired. Most patients have a left angular gyrus lesion, but it is also seen in lesions in other locations—even the frontal lobe.

*Pure word deafness.* These patients cannot understand the spoken word at all, though hearing is intact. They comprehend the written word normally and can read aloud without problems. The disorder is seen with bilateral temporal lobe lesions or a single deep left-sided temporal lesion that separates Wernicke's area from the primary auditory cortex. Many of these cases arise in the recovery phase of Wernicke's aphasia.

*Alexia without agraphia (pure word blindness).* Patients comprehend the spoken word normally but cannot read. They can understand letters and words traced in their palms or spelled aloud. Words are written correctly either spontaneously or to dictation, but in a few minutes the patient cannot read what he just wrote. The lesion involves the splenium of the corpus callosum plus the left visual cortex. A right homonymous hemianopia is present. Visual information reaches the right visual cortex from the left visual field, but it cannot be transmitted across the corpus callosum to the left visual association area and angular gyrus, which are normal. Tactile stimuli from either hand can reach these areas however, accounting for the ability to "read" words traced on the palms (this is the same route used in braille).

*Alexia with agraphia.* Patients cannot read, write, or spell. The condition is often associated with Gerstmann's syndrome plus anomia and constructional apraxia. These elements make up the syndrome of lesions of the dominant angular gyrus. Gerstmann's syndrome is composed of finger agnosia, right-left disorientation, acalculia, and agraphia.

*Language disturbances with left thalamic hemorrhage.* Mohr et al (1975) and Reynolds et al (1978) have reported left thalamic hemorrhage associated with language disturbance. These patients had virtually intact language testing when fully alert, but often went suddenly into a state of logorrheic paraphasia resembling delirium. Repetition from dictation was intact.

Table 66.4 summarizes the types of aphasia. Table 66.5 lists a few clues helpful in anatomical localization. Figure 66.2 shows the location of perisylvian structures and the border zone.

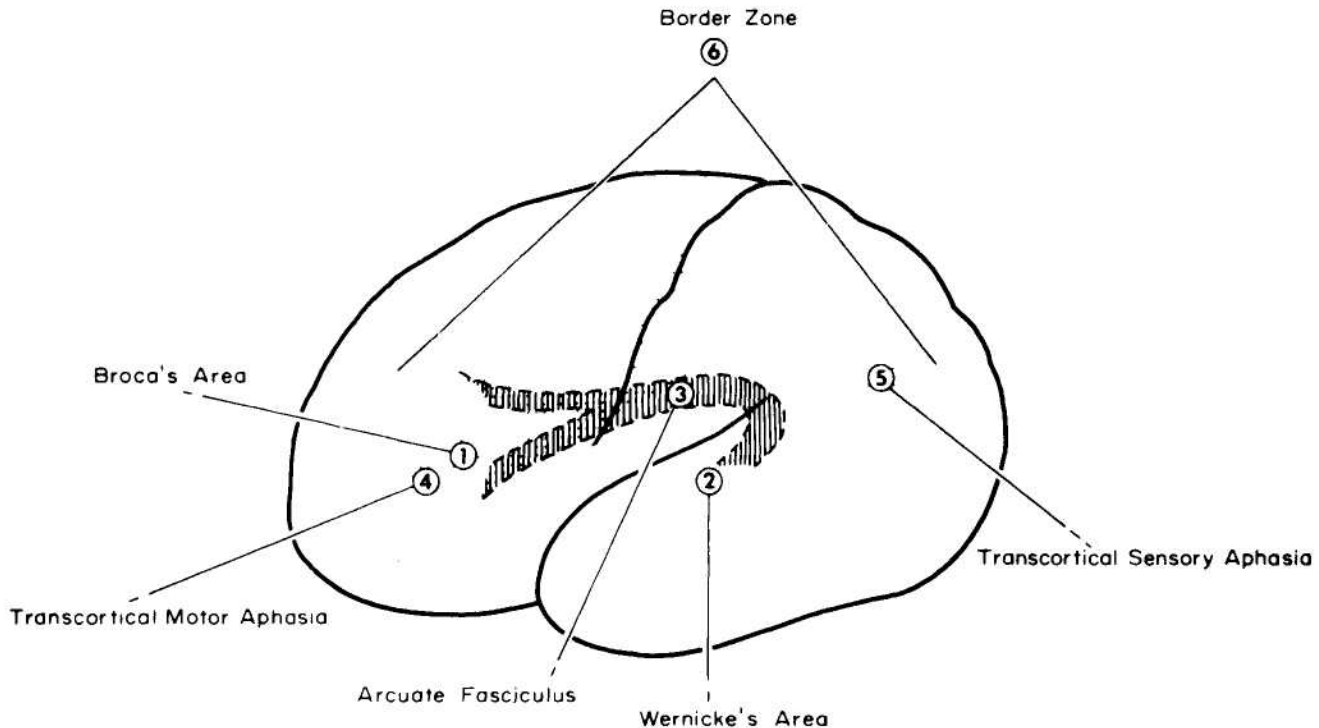
### Cause and Prognosis

Many cases of left and right hemispheric dysfunction are due to vascular lesions and neoplasms. Trauma accounts for others. In certain disease states, especially those characterized by delirium, there occur the so-called nonaphasic disorders of speech. These are separated from aphasias only with much difficulty. The reader is referred to Geschwind (1964) for a further discussion.

Brust et al (1976) studied 850 stroke patients and discovered aphasia in 21%. Of the patients with aphasia, 32% had the fluent type (usually Wernicke's) and 68% had nonfluent aphasia (most often a mixed type). Hemiparesis was present in 74% of the patients with fluent aphasia and 95% of those with nonfluent aphasia. Homonymous hemianopia occurred in 32% of fluent and 55% of nonfluent aphasics.

**Table 66.5**  
Helpful Clues in Aphasia Localization

Clue	Anatomical localization	Comment
Repetition disturbed	Perisylvian speech areas	Broca's, conduction, Wernicke's
Repetition intact	Border zone or watershed area	Transcortical aphasias
Pronounced phonemic paraphasia	Supramarginal gyrus	Mild to moderate phonemic paraphasia seen with other lesions; presence of buccofacial apraxia clinches supramarginal gyrus localization
Buccofacial apraxia	Suprasylvian (frontoparietal) operculum	Often found in conduction aphasia, Broca's aphasia, and mixed aphasia where there is damage to the suprasylvian area
Severe anomia	Inferior temporooccipital juncture	Often associated with an upper right quadrantanopia



**Figure 66.2**

Anatomy and localization of some of the aphasias. Modified from Benson DF, Geschwind N. The aphasias and related disturbances. In: Baker AB, Baker LH, eds. *Clinical neurology*. Hagerstown, Md: Harper & Row, 1977;1:chap 8. Used with permission.

With regard to prognosis, 32% of the patients with non-fluent aphasia and 12% of those with fluent aphasia died in four to twelve weeks.

The clinical significance of disorders of phonation is discussed in Chapter 63 on nerves IX and X. Disturbances of articulation can be caused by lesions involving nerves V, VII, IX, X, XI, and XII. These are discussed in the appropriate chapters.

One disorder of articulation deserves particular mention: pseudobulbar palsy is caused by bilateral lesions involving the supranuclear corticobulbar fibers to the nuclei of the cranial nerves supplying the articulatory muscles, that is, the muscles of the face, jaws, tongue, and larynx. It is caused by any process which bilaterally interrupts the supranuclear innervation. This includes strokes affecting both sides of the brain, multiple sclerosis, and the hypertensive lacunar state. The latter two interfere with the innervation by multiple small lesions. The patients show emotional incontinence with frequent randomly occurring bouts of crying (usually) or laughter. A notable feature is progressive difficulty in using lips, jaws, tongue, and pharynx. The problem usually begins with the more complex motor actions such as speaking but ultimately involves even swallowing. As might be expected of a supranuclear disorder, the motor power is present but the patient does not know how to use the muscles.

Disorders of the minor hemisphere are included under Basic Science.

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